AOT 302	HEAT TRANSFER	CATEGORY	L	T	P	CREDIT
		PCC	3	1	0	4

Preamble: In this course the student will learn the basic concepts of heat transfer, as it is applied to the design of engineering devices and systems, that involve transfer of heat or thermal energy. The study involves heat transfer processes by conduction, convection and radiation, their mathematical formulations and their practical solutions. Attention is also given to special heating problems encountered in high-speed high temperature flows.

Prerequisite: Knowledge of thermodynamics and mathematical theory of partial differential equations

Course Outcomes: After the completion of the course the student will be able to

CO 1	Formulate and solve heat conduction problems with temperature dependent thermal properties, heat generation and across multi-layer materials.
CO 2	Solve forced and free convection problems using boundary layer concepts and empirical solutions. Use of important non-dimensional parameters
CO 3	Solve radiation problems using basic radiation laws like Planck'law, Wein's displacement law and Kirchoff's law
CO 4	Solve design problems involving heat exchangers
CO 5	Develop familiarity with special problems encountered in high speed flights and design ofcooling systems and ablative heat shields

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12
CO 1	3	3	2	1	1							
CO 2	3	3	2	1	1							
CO 3	3	3	2	1	1							
CO 4	3	3	2	1	1							
CO 5	3	3	2	1	1							

Assessment Pattern

Bloom's Category	**Continuous Assessment Tests**		**End Semester Examination**
	1	**2**	
Remember	10	10	15
Understand	10	10	15
Apply	30	30	70
Analyse			
Evaluate			
Create			

Mark distribution

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Continuous Internal Evaluation Pattern:

Attendance : 10 marks
Continuous Assessment Test (2 numbers) : 25 marks
Assignment/Quiz/Course project : 15 marks

End Semester Examination Pattern: There will be two parts; Part A and Part B. Part A contain 10 questions with 2 questions from each module, having 3 marks for each question. Students should answer all questions. Part B contains 2 questions from each module of which student should answer any one. Each question can have maximum 2 sub-divisions and carry 14 marks.

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. What are the basic modes of heat transfer and the laws governing them?
2. What is the general form of Fourier's heat conduction law?
3. What are the effects of temperature dependent thermal conductivity and heat generation?
4. What is electrical analogy and its applications?
5. What is lumped mass concept for transient heat conduction? Under what conditions it is valid?
6. What are similarity solutions and their applications to transient heat conduction?
7. What are Biot and Fourier numbers? How to use Heisler's charts for transient heat transfer problems?

Course Outcome 2 (CO2):

1. What are the differences between natural free convection and forced convection?
2. What are the non-dimensional parameters governing these convective heat transfer processes?
3. How does free convection occur in atmosphere?
4. How does free convection occur over a vertical flat plate?
5. How we can use the concept of boundary layers in analysing laminar and turbulent free convection?
6. How to analyse free convection process in flows between parallel plates, over a flat plate and in circular pipes?
7. What are the needs and applications of numerical methods for heat transfer analysis? How to solve steady state heat conduction problems using finite difference methods?

Course Outcome 3 (CO3):

1. What are the fundamental processes of radiation heat transfer?

2. What are the radiative properties of materials and their spectral dependence?
3. What are the fundamental laws governing radiative heat transfer?
4. What is the concept of radiosity?
5. What is the radiation shape factor and its dependence on geometries? How to use standard charts for specific geometries using shape factor algebraic laws?
6. What are radiation heat shields and how to design them?

Course Outcome 4 (CO4):

1. What are heat exchangers and their applications? How they are classified?
2. What are the temperature distributions in parallel flow and counter flow heat exchangers?
3. How to use LMTD and e-NTU methods to design heat exchangers and what are their limitations?
4. What are special heat exchangers like boilers and condensers?
5. What are compact heat exchangers?

Course Outcome 5 (CO5):

1. What are the heat transfer problems in high-speed hypersonic flights?
2. What is the concept of adiabatic wall temperature and the idea of recovery factor?
3. What does Eckert number signify? What are the various cooling methods for combustion chambers and rockets and missiles?
4. What are the materials used for high speed thermal protection systems?
5. What is ablation process? How to analyse one dimensional ablation using moving boundary concept?

Model Question paper

QP CODE: **Reg No: -------------------------**

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY SIXTH SEMESTER B. TECH DEGREE EXAMINATION

MONTH & YEAR

Course Code: AOT 302

HEAT TRANSFER

Max.Marks:100 **Duration: 3 Hours**

PART A

Answer all Questions.

(Each question carries 3 Marks)

1. Write down the general three-dimensional heat conduction equation with heat generation and show that for the case of steady heat transfer through a material of constant physical properties with no heat generation this equation reduces to the Laplace's equation.

2. The flat roof of an electrically heated home measures 8m by 6m and it consists of 25 cm thick concrete slab, whose conductivity k = 0.8 W/m/K. If the interior of the house is maintained at 25 deg C while the outside ambient temperature is 0 deg C, calculate the heat loss through the roof during one night for 10 hours

3. What is critical thickness of insulation?

4. Define Nusselt number and explain its physical significance

5. Explain the need for numerical solutions to the heat transfer problems. What are the different types of boundary conditions that are normally used in obtaining the solutions

6. Distinguish bewteen Irradiation G and Radiosity J

7. What is Wein's displacement law? Using this law, estimate the surface temperature of the Sun knowing that the its radiant energy has peak at a wave length λ = 0.52 μm.

8. Briefly explain how the different types of heat exchangers can be classified

9. Mention different types of cooling methods adopted in the design of structure of high-speed vehicles

10. A missile is flying at Mach No. Of 6 at an altitude of 14 Km where the ambient temperature is 209 deg K. What is the total temperature and the adiabatic wall temperature if the flow is assumed to be laminar?

PART B

Answer any one full question from each module.

(Each question carries 14 Marks)

Module 1

11. A 0.5m diameter thin-walled spherical tank containing liquid nitrogen at 80 deg K is covered with a 25 mm thick insulation layer made of compressed silicon powder having a thermal conductivity of 0.0017 W /m/K. The outer surface of the tank has a convective heat transfer coefficient of 20 W/m^2/K and the ambient temperature is 37 deg C. Calculate the heat transfer rate and the amount of boil-off of the liquid nitrogen, taking the density ρ = 804 Kg/m^3 and the latent heat of vaporisation as 200 KJ/Kg.

(14)

12. a) If the conductivity of a solid material varies linearly with temperature as $k(T) = k_o(1+\beta T)$, show that the heat flux across a wall of thickness L whose end surfaces are maintained at temperatures T_1 and T_2 is given by $q_w = -k_{av}(T_2-T_1)/L$ where k_{av} is the thermal conductivity evaluated at the average temperature T_{av} given by $(T_1 + T_2) / 2$.

(8)

b)Air flows over a rectangular plate having dimensions 0.5 m x 0.25 m. The free stream temperature of the air is 300°C. At steady state, the plate temperature is 40C. If the convective heat transfer coefficient is 250 W/m2/K, determine the heat transfer rate from the air to one side of the plate.

(6)

Module 2

13. a) An electrically heated thin foil of length 25 mm and width 8 mm is used as a sensor for measuring the velocity of an air stream that has a temperature of 32 deg C. The foil is internally heated from both sides of the foil and dissipates 0.5 W. Using this data and the air properties at 20 deg C estimate the velocity of the air stream

(10)

b)Explain the need for numerical solutions to the heat transfer problems. What are the different types of boundary conditions that are normally used in obtaining the solutions?

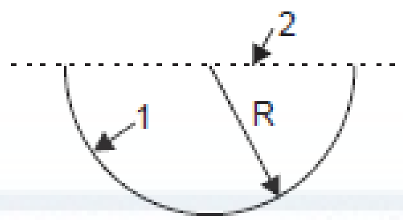
(4)

14. a) A solar concentrator causes a heat flux of 2000 W/m^2 on tube of 60 mmID.Pressurized water flows through the tube at a rate of 0.01 kg/s. If the bulk temperature at inletis 20°C, what will be the length required to heat the water to a bulk temperature of 80°C. Alsofind the wall temperature at exit. Assume fully developed conditions.

(14)

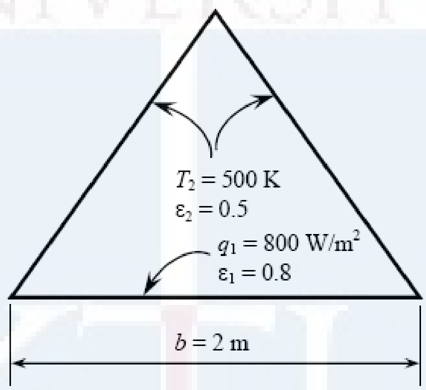
Module 3

15. a)A long hemispherical groove is as shown below. Find the view factor F_{12}



(9)

b)Distinguish between Irradiation G and Radiosity J (5)



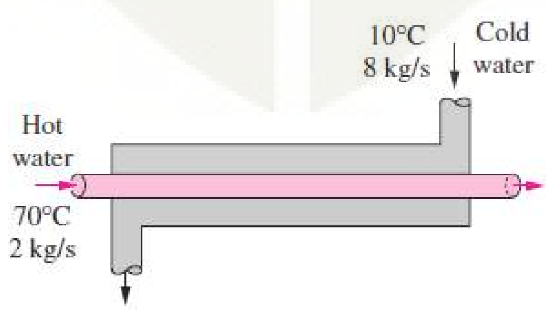
16. A furnace is shaped like a long equilateraltriangular duct (as shown above) where the width of each side is 2 m. Heat is supplied from the base surface, whose emissivity is $\varepsilon_1 = 0.8$, at a rate of 800 W/m^2 while the side surfaces, whose emissivities are 0.5, are maintained at 500 K. Neglecting the end effects, determine the temperature of the base surface. Can you treat this geometry as a two-surface enclosure?

(14)

Module 4

17. a) Show that the use of lograthmic mean temperature difference (LMTD) always results in conservative design of heat exchangers compared to using the arithmetic temperature difference (AMTD).

(6)



b) Cold water enters a counter-flow heat exchanger at 10 deg C at a rate of 8 kg/s, where it is heated by a hot water stream that enters at 70 deg C at a rate 2 kg/s, as shown in the figure above. Assuming that the specific heat of water remains constant at 4184 J/kg/K, determine the maximum possible heat transfer rate and the corresponding outlet temperatures of cold and hot water streams.

(8)

18. a) Briefly explain how the different types of heat exchangers can be classified (4)

b) A concentric tube heat exchanger is used to cool the lubricating oil of a large diesel engine The inner tube is 30 mm diameter and is 2 mm thick and is made of stainless steel k=16 W/m/K. Cooling water flows through the inner tube at a rate of 0.3 Kg.s . The outer tube is 50 mm diameter through which oil flows at a rate of 0.15 Kg/s. The oil cools from 90 deg C to 50 deg C and water is available at 10 deg C. Calculate the length of the tube for parallel flow and counter flow heat exchangers configurations

(10)

Module 5

19. a) Show that the velocity of an ablating surface is given by

$V_a = \dfrac{q_{c,w}}{\rho L_f + \rho c\left(T_m - T_{w,i}\right)}$ where q_{cw} is the heat flux L_f is the heat of ablation T_m is the ablation temperature T_{wi} is the initial surface temperature and ρ is the density

(7)

b) For a constant heat flux of 3 MW / m^2, compute the ablation velocity using the following property values Cp 1256 J/Kg/K ρ = 1600 Kg/m^3 k = 0.8655 W/m/K,

Latent Heat = 9.304 MJ/kg. $T_{ablation}$ = 1650 deg C $T_{initial}$ = 15 deg C

(7)

20. Starting from unsteady one-dimensional heat conduction equation, derive the governingequation for a moving boundary problem that moves with a velocity V, by thecoordinate transformation $\eta = y - V_a t$

$$\frac{d^2T}{d\eta^2} + \frac{V_a}{\alpha}\frac{dT}{d\eta} = 0$$

Write down also the general solution of this equation

(14)

Syllabus

Module 1

Introduction to heat transfer and its relation to thermodynamics. Basic modes of heat transfer and the laws governing them. Fourier's law and derivation of general three-dimensional heat conduction equation and the boundary conditions. One dimensional steady state heat conduction in composite mediums and with variable thermal properties and heat generation. Idea of electrical analogy and use of thermal resistance and capacitance concepts. Idea of critical thickness of insulation. Heat transfer in extended surfaces and design of fins. One dimensional transient heat conduction analysis and the idea of lumped mass analysis and its validity. Use of similarity solutions for heat transfer problems in semi-infinite and infinite solids. Application of non-dimensional parameters Fourier number and Biot number and the use of transient temperature (Heisler's) charts

Module 2

Free and forced convection and non-dimensional parameters Nusselt, Prandtl and Eckert and Grashof numbers. Free convection in atmosphere. Free convection on a vertical flat plate. Empirical relation for heat transfer. Concept of Laminar and turbulent convective heat transfer analysis using the boundary layer concepts in flows between parallel plates. over a flat plate and in a circular pipe. Need and application of numerical techniques in solving heat transfer problems. Use of finite difference method for solving steady stat heat conduction problems.

Module 3

Introduction to physical mechanism of radiation heat transfer. Radiation properties of materials and their wave length dependence. Planck's radiation Law. Wein's displacement law and Kirchoff's law. Formulation of radiation shape factors for different geometries Concept of radiosity. Stefan-Boltzmann law Heat exchange between non-black bodies. Design of radiation shields.

Module 4

Heat exchangers and their classifications and applications. Temperature distribution in parallel flow and counter-flow heat exchangers. Concept of overall heat transfer coefficient. Design of heat exchangers using LMTD and e-NTU methods. Special heat exchangers like boilers and condensers and compact heat exchangers

Module 5

Heat transfer problems in high-speed hypersonic flows. Adiabatic wall temperature and the idea of recovery factor and Eckert number. Various cooling techniques and Heat transfer in combustion chambers. Ablation process materials and their applications in thermal protection against aerodynamic heating. Concept of moving boundary value problems and its application to the design of ablative heat shields.

Text Books:

1. S.C. Sachdeva, "Fundamentals of Engineering Heat & Mass Transfer", Wiley Eastern Ltd., New Delhi,1981.

2. Yunus A. Cengel, Heat Transfer – A Practical Approach, Tata McGraw Hill Edition, 2003.
3. P.K. Nag, "Heat and Mass Transfer ", Third edition, Tata=McGraw Hill publications, 2011

4. F.P. Incropera and D.P. Dewitt, “Fundamentals of Heat and Mass Transfer “, John Wiely and Sons Publications, 2006.

5. FrankKreith, Raj M. Manglik, Mark S. Bohn, ‘Principals of Heat Transfer’, Seventh Edition, Cengage Learning, 2011.

Reference Books:

1. C.Y.Chow, “Introduction to Computational Fluid Dynamics”, John Wiley, 1979.
2. J.P. Holman, “Heat Transfer”, McGraw-Hill Book Co., Inc., New York, 6e, 1991.
3. John H. Lienhard, “A Heat Transfer Text Book”, Prentice Hall Inc., 1981
4. P. S. Ghoshdasidar , “Computer simulation of flow and Heat transfer” McGraw-Hill Book Co, Inc, NewDelhi, 1998
5. M. NecatiOzisik,’Heat Transfer, A Basic Approach’ , McGraw Hill, New York, 2005.

E-Books/Web references:

1. John H Lienhard, ‘A Text book of Heat Transfer’, 4th Edition,
2. NPTEL Heat Transfer course for Mechanical Engineering,http://nptel.ac.in/courses/112101097/
3. Heat Transfer, Chris Long & Naser Sayma, www.bookboon.com

Course Contents and Lecture Schedule

No	Topic	No. of Lectures
1	**Module 1**	
1.1	Introduction Basic modes of heat transfer - Fourier’s law and derivation of general three-dimensional heat conduction equation and the boundary conditions.	2
1.2	One dimensional steady state heat conduction in composite mediums and with variable thermal properties and heat generation. Idea of electrical analogy and use of thermal resistance and capacitance concepts. Idea of critical thickness of insulation.	2
1.3	Heat transfer in extended surfaces and design of fins.	2
1.4	One dimensional transient heat conduction analysis and the idea of lumped mass analysis and its validity.	1
1.5	Use of similarity solutions for heat transfer problems in semi-infinite and infinite solids.	1
1.6	Application of non-dimensional parameters Fourier number and Biot number and the use of transient temperature (Heisler’s) charts	1
2	**Module 2**	
2.1	Free and forced convection and non-dimensional parameters Nusselt, Prandtl and Eckert and Grashof numbers.	1
2.2	Free convection in atmosphere. Free convection on a vertical flat plate. Empirical relations for heat transfer.	2
2.3	Concept of Laminar and turbulent convective heat transfer analysis using the boundary layer concepts	2

2.4	Analysis of free convection between parallel plates. over a flat plate and in a circular pipe.	2
2.5	Need and application of numerical techniques in solving heat transfer problems. Use of finite difference methods for steady state heat conduction problems	2
3	**Module 3**	
3.1	Introduction to physical mechanism of radiation heat transfer.	1
3.2	Radiation properties of materials and their wavelength dependence. and Planck’s radiation Law. Wein’s displacement law and Kirchoff’s law.	2
3.3	Formulation of radiation shape factors for different geometries Concept of radiosity. Use of standard charts	2
3.4	Stefan-Boltzmann law Heat exchange between non-black bodies.	2
3.5	Design of radiation shields. Heat transfer in enclosed spaces	2
4	**Module 4**	
4.1	Heat exchangers and their classifications and applications.	2
4.2	Temperature distribution in parallel flow and counter-flow heat exchangers.	2
4.3	Concept of overall heat transfer coefficient.	2
4.4	Design of heat exchangers using LMTD and e-NTU methods.	3
5	**Module 5**	
5.1	Heat transfer problems in high-speed hypersonic flows and aerodynamic heating	2
5.2	Adiabatic wall temperature and the idea of recovery factor and Eckert number.	1
5.3	Various cooling techniques and Heat transfer in combustion chambers.	2
5.4	Ablation process, materials and its applications in thermal protection against aerodynamic heating.	2
5.5	Concept of moving boundary value problems and its application to the design of ablative heat shields.	2